AN OVERVIEW OF RECENT SEISMIC REFRACTION EXPERIMENTS IN CENTRAL EUROPE

A. GUTERCH[1], M. GRAD[2], A. ŠPIČÁK[3], E. BRÜCKL[4], E. HEGEDÜS[5], G.R. KELLER[6], H. THYBO[7] AND CELEBRATION 2000, ALP 2002, SUDETES 2003 WORKING GROUPS

WORKING GROUPS: K. ARIC, S. ACEVEDO, I. ASUDEH, M. BEHM, A. A. BELINSKY, T. BODOKY, R. BRINKMANN, M. BROŽ, E. BRÜCKL, W. CHWATAL, R. CLOWES, W. CZUBA, T. FANCSIK, B. FORKMANN, M. FORT, E. GACZYŃSKI, H. GEBRANDE, H. GEISSLER, A. GOSAR, M. GRAD, H. GRASSI, R. GRESCHKE, A. GUTERCH, Z. HAJNAL, S. HARDER, E. HEGEDÜS, A. HEMMANN, S. HOCK, V. HOECK, P. HRUBCOVÁ, T. JANIK, G. JENTZSCH, P. JOERGENSEN, G. KAIP, G.R. KELLER, K. KOMMINAHO, M. KORN, O. KAROUSOVÁ, S.L. KOSTIUCHENKO, F. KOHLBECK, D. KRACKE, M. MAJDAŃSKI, M. MALINOWSKI, K.C. MILLER, A.F. MOROZOV, E.-M. RUMPFHUBER, CH. SCHMID, C. SNELSON, A. ŠPIČÁK, P. ŚRODA, F. SUMANOVAC, E. TAKACS, H. THYBO, T. TIIRA, Č. TOMEK, J. VOZÁR, F. WEBER, M. WILDE-PIÓRKO, J. YLINIEMI, A. ŻELAŹNIEWICZ

1 Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland
2 Institute of Geophysics, University of Warsaw, Poland
3 Geophysical Institute, Academy of Sciences of the Czech Republic, Prague, Czech Republic
4 Technical University, Vienna, Austria
5 Eötvös Loránd Geophysical Institute, Budapest, Hungary
6 University of Texas at El Paso, USA
7 University of Copenhagen, Denmark

1. INTRODUCTION

Beginning in 1997, Central Europe has been covered by an unprecedented network of seismic refraction experiments (Figure 1). These experiments (POLONAISE'97, CELEBRATION 2000, ALP2002, and SUDETES 2003) have only been possible due to a massive international cooperative effort. They along with the BOHEMA teleseismic experiment are providing exciting new insights into the structure and evolution of the lithosphere in this region (*Plomerová et al., 2003*). The papers that follow provide technical descriptions of these experiments with the exception of POLONAISE'97 where this information is published in a paper by *Guterch et al., (1999)*. In fact, papers have been published providing full interpretations of the POLONAISE'97 profiles (*Środa et al., 1999*; *Jensen et al., 1999*; *Grad et al., 2002*; *Czuba et al., 2002*; *and Janik et al*., *2002*). In addition, a 3-D velocity model has been derived and interpreted (*Środa et al, 2002*), and the final interpretation of the longest profile P4. Here we would like to discuss some of the geologic features, scientific questions, and international efforts that the refraction experiments share.

Fig. 1. Index map showing the locations of major seismic refraction experiments in Central Europe.

2. REGIONAL GEOLOGIC/TECTONIC SETTING

As reflected in structures within the Trans-European Suture Zone (TESZ), Alps and Carpathians, Bohemian Massif, and Pannonian basin regions (Figure 2), Central Europe has experienced a complex tectonic history that includes three geologically recent periods of mountain building due to accretion of terranes during the Caledonian and Variscan orogenies and the collisional events of the Alpine orogeny. In addition, extension has affected region on several occasions. First, the super-continent Rodinia broke-up near the Cambrian-Precambrian boundary and formed the rifted margin of southwest Baltica (e.g., *Poprawa et al., 1999*); extension was widespread after the Variscan orogeny especially in the Polish-North German basin; and the Eger rift formed during the Cenozoic.

The TESZ region (Caledonides, Tornquist Teisseyre zone area, Figure 2) is a broad zone of deformation that extends across Europe from the British Isles to the Black Sea region that formed as Europe was assembled from a complex collage of terranes during the late Paleozoic (e.g., *Pharaoh, 1999*). These terranes were accreted along the margin of Baltica (East European craton) that was formed during the break-up of Rodinia. The tectonic evolution of this region shares many attributes with the Appalachian/Ouachita origin (e.g., *Keller and Hatcher, 1999*) and is certainly of global importance to studies in terrane tectonics and continental evolution. The TESZ is far more complex than a single suture but in a broad sense is the boundary between the accreted terranes and Baltica. The Bohemian Massif is mostly located in the Czech Republic and is a large, complex terrane whose origin can be traced to northern Gondwana (Africa). In southern Poland, several structural blocks such as the Malopolska Massif (Figure 2) are located adjacent to Baltica and were probably transported laterally along it similar to the Cenozoic movement of terranes along the western margin of North America.

The younger Carpathian Mountains and Pannonian basin were also targeted by these experiments. These features are the result of intricate Mesozoic/Cenozoic plate interactions in the Mediterranean region as the Tethys Ocean closed during convergence of Europe and Afro-Arabia. During the Cenozoic, complex interactions among small plates caused the Carpathian arc to evolve into its strongly arcuate shape (Figure 2). These plate interactions have been interpreted to involve subduction of oceanic areas and produced considerable Neogene volcanism. Back arc extension was the dominant process that formed the Pannonian basin that contains up to 8 km of Neogene strata in its sub-basins (e.g., *Posgay et al., 1995*). This region is still tectonically active as evidenced by seismicity that extends to depths of ~ 200 km in the Vrancea region north of Bucharest (Figure 2) (e.g., *Linzer et al., 1998*) that was the target of another international collaborative experiment that was completed in September of 2001 (*Hauser et al., 2001*).

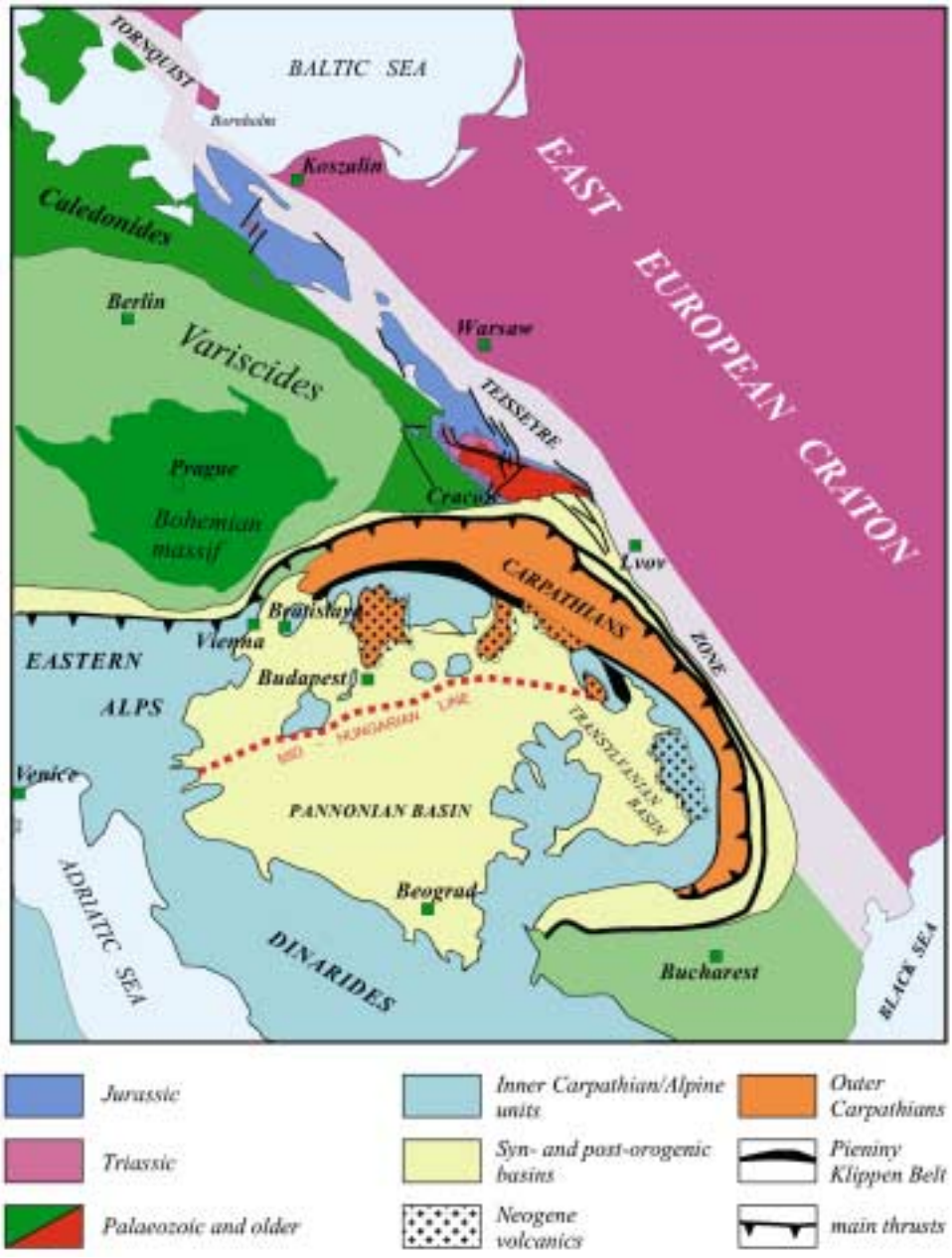

Fig. 2. Tectonic map of Central Europe showing the features targeted by the CELEBRATION 2000, ALP 2002 and SUDETES 2003 seismic experiment.

3. A NEW GENERATION OF SEISMIC EXPERIMENTS

The EUROPROBE program focused considerable attention on the structure and tectonics of Central Europe and created an environment that spawned a new generation of large seismic experiments in the region. Since the lithospheric structure in the region is very complex, the need for a 3-D approach was recognized early. The first of the new experiments was POLONAISE'97 (*Guterch et al., 1999*) and showed how much could he learned from even modest 3-D coverage (*Środa et al., 2002*). A series of even larger experiments has followed in rapid succession, and these experiments (CELEBRATION 2000, ALP 2002, and SUDETES 2003) are the focus of this sequence of special contributions (*Guterch et al., 2003*; *Brueckl et al.,2003*; *Grad et al., 2003*). These experiments also relate to German KTB project, the BOHEMA seismic tomography experiment, and numerous Czech-German projects on the geodynamics of the West Bohemia/Vogtland seismically active region. As a result of these experiments, a network of seismic refraction profiles now extends along the Trans-European Suture Zone region of Poland and the Bohemian Massif, Pannonian basin, through the Carpathians and Alps to the Adriatic Sea and the Dinarides (Figure 1).

The EUROPPROBE project helped to form the basis for these projects through the framework provided by its TESZ (*Thybo et al., 1999*; *2002*), EUROBRIDGE (East European craton, *Bogdanova et al., 2001*) and PANCARDI initiatives (*Decker et al., 1998*). The principal specific scientific goals of these experiments are to:

- Investigate the deep structure of the southwestern margin of the East European craton (southern Baltica) and its relationships to younger terranes
- Delineate the major terranes and crustal blocks in the TESZ region
- Investigate the origin and structural framework of the Pannonian basin and its sub-basins
- Investigate the nature and extent of thrust faulting along the northern front of the Carpathian Mountains
- Investigate the structure and evolution of the eastern Alps and their relationships with adjacent features
- Investigate the structural relationships between the structural elements of the Bohemian Massif and adjacent features
- Construct a 3-D model of the lithospheric structure in the area
- Evaluate the implications of the earth models derived for natural resources and earthquake hazards
- Evaluate and develop geodynamic models for the tectonic evolution of the region.

The POLONAISE'97 experiment (*Guterch et al., 1999*) set the stage for the beginning of a new phase of international cooperation to study the lithospheric structure of Central Europe. This experiment was very effective, but it also showed that much additional seismic data coverage was needed to unravel the complex structure of this region. Thus, a consortium of 28 institutions organized the massive CELEBRATION 2000 experiment that covered significant parts of thirteen countries. The Austrian group led the subsequent ALP 2002 experiment that targeted the Eastern Alps and adjacent areas of Hungary, Slovenia, Croatia, and the Czech Republic. The groups from the Czech Republic and

Poland led the most recent experiment (SUDETES 2003) that covered most of the Czech Republic and Poland, and as well as, adjacent parts of Germany, Slovakia, and Hungary. Together, these experiments will provide an unprecedented 3-D image of the evolution and assembly of a continent.

References

Bogdanova S.V., Gorbatschev R., Stephenson R.A., and Guterch A. (eds), 2001. EUROBRIDGE: Palaeoproterozoic accretion of Fennoscandia and Sarmatia. *Tectonophysics* (Special Issue), **339**, 1-2, 237 pp.

Brückl E., Bodoky T., Hegedüs E., Hrubcová P., Gosar A., Grad M., Guterch A., Hajnal Z., Keller G.R., Špičák A., Sumanovac F., Thybo H., Weber F. and ALP 2002 Working Group, 2003. ALP 2002 Seismic Experiment. *Stud. Geophys. Geod*., this issue.

Czuba W., Grad M., Luosto U., Motuza G., Nasedkin V. and POLONAISE P5 Working Group, 2002. Upper crustal seismic structure of the Mazury complex and Mazowsze massif within the East European Craton in NE Poland. *Tectonophysics*, **360**, 115-128.

Decker K., Lillie B., and Tomek C. (eds), 1998. PANCARDI: The lithospheric structure and evolution of the Pannonian/Carpathian/Dinaride region. *Tectonophysics* (Special issue), **297**, 1-4.

Grad M., Keller G.R., Thybo H., Guterch A. and POLONAISE Working Group, 2002. Lower lithospheric structure beneath the Trans European Suture Zone from POLONAISE '97 seismic profiles. *Tectonophysics*, **360**, 153-168.

Grad M., Špičák A., Keller G.R., Guterch A., Brož M., Hegedüs E. and SUDETES 2003 Working Group, 2003. SUDETES 2003 Seismic Experiment. *Stud. Geophys. Geod.*, this issue.

Guterch A., Grad M., Thybo H. and Keller G.R., 1999. POLONAISE '97 – an international seismic experiment between Precambrian and Variscan Europe in Poland, *Tectonophysics,* **314***,* 101-121.

Guterch A., Grad M., Keller G.R., Posgay K., Vozár J., Špičák A., Brückl E., Hajnal Z., Thybo H., Selvi O. and CELEBRATION 2000 Experiment Team, 2003. CELEBRATION 2000 Seismic Experiment. *Stud. Geophys. Geod.*, this issue.

Hauser F., Raileanu V., Fielitz W., Bala A. and Prodehl C., 2001. VRANCEA99 - The crustal structure between the southeastern Carpathians and the Moesian Platform from a refraction seismic profile in Romania. *Tectonophysics*, **340**, 233-256.

Janik T., Yliniemi J., Grad M., Thybo H., Tiira T. and POLONAISE P2 Working Group, 2002. Crustal structure across the TESZ along POLONAISE'97 seismic profile P2 in NW Poland. *Tectonophysics*, **360**, 129-152.

Jensen S.L., Janik T., Thybo H., and POLONAISE Profile 1 Working Group, 1999. Seismic structure of the Paleozoic platform along POLONAISE '97 profile P1 in northwestern Poland. *Tectonophysics*, **314**, 123-143.

Keller G.R., and Hatcher, R.D. Jr., 1999. Some comparisons of the structure and evolution of the southern Appalachian-Ouachita orogen and portions of the Trans-European suture zone region. *Tectonophysics*, **314**, 43-68.

Linzer H.G., Frisch W., Zweigel P., Girbacea R., Hann H.P., and Moser, F., 1998. Kinematic evolution of the Romanian Carpathians. *Tectonophysics*, **297**, 113-156.

Pharaoh T.C., 1999. Palaeozoic terranes and their lithospheric boundaries within the Trans-European suture zone (TESZ): a review. *Tectonophysics,* **314**, 17-41.

Plomerová J., Achauer U., Babuška V., Granet M. and BOHEMA Working Group, 2003. Passive seismic experiment to study lithosphere-asthenosphere system in the western part of the Bohemian Massif. *Stud. Geophys. Geod.*, this issue.

Poprawa P., Sliaupa S., Stephenson R., and Lazauskiene J., 1999. Late Vendian-Early Palaeozoic tectonic evolution of the Baltic basin: regional tectonic implications from subsidence analysis. *Tectonophysics,* **314**, 218-239.

Posgay K., Bodoky T., Hegedüs E., Kovácsvölgyi S., Lenkey L., Szafián P., Takács E., Tímár Z., and, Varga G., 1995. Asthenospheric structure beneath a Neogene basin in southeast Hungary. *Tectonophysics,* **252**, 467-484.

Środa P. and POLONAISE Profile 3 Working Group, 1999. P- and S- wave velocity model of the southwestern edge of the Precambrian East European craton: POLONAISE ' 97, profile P3. *Tectonophysics*, **314**, 175-192.

Środa P., Czuba W., Grad M., Guterch A., Gaczyński E. and POLONAISE Working Group, 2002. Three-dimensional seismic modelling of crustal structure in the TESZ region based on POLONAISE'97 data. *Tectonophysics,* **360**, 169-185.

Thybo H., Pharaoh T., and Guterch A. (eds), 1999. Geophysical investigations of the Trans-European suture zone. *Tectonophysics* (Special Issue), **314**, 1-3, 350 pp.

Thybo H., Pharaoh T., and Guterch A. (eds), 2002. Geophysical investigations of the Trans-European suture zone II. *Tectonophysics* (Special Issue), **339**, 1-2, 237 pp.